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INTERIM STATUS AND RECOMMENDATIONS FOR THE ENGINEERING INFORMATION SYSTEM (EIS) PROGRAM

Robert M. Rolfe
Dennis W. Fife
Edgar H. Sibley
Herbert R. Brown

March 1990

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Office of the Assistant Secretary of Defense for
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IDA
INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

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Robert M. Rolfe, Dennis W. Fife, Edgar H. Sibley, Herbert R. Brown

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IDA Document D-693, Interim Status and Recommendations for the Engineering Information System (EIS) Program, provides an analysis of the Engineering Information System (EIS) framework performed by the Institute for Defense Analyses (IDA). IDA evaluated the present work on the EIS, made recommendations for improving the effectiveness of EIS products, and identified the needed tasks and future considerations. This document is the results of tracking the program implementation, starting with the original requirements and progressing through in-process documents produced for the EIS program, and discussions from meetings and workshops with the EIS contractors and Advisory Committees.

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Preface

The purpose of IDA Document D-693, Interim Status and Recommendations for the Engineering System (EIS) Program, is to make available the preliminary and tentative results of analyses of the EIS program. This document partially fulfills the objective of Task Order T-B5-490, Integrated Diagnostics for Weapons and Support Systems, which is to evaluate the present work on the EIS, make recommendations for improving the effectiveness of EIS products, and identify the remaining tasks to be completed. The document will be used by a large audience, comprising managers, users, and implementors of the EIS and other similar systems.

This document was reviewed on 16 February and 27 March 1990 by members of the following Computer and Software Engineering Division (CSED) peer review: Richard Wexelblat, Terry Mayfield, Robert Winner, Joseph Linn and Larry Reeker. In addition, Nick Naclerio, Bruce Rasmusen and members of the Honeywell contractor team participated in an external review of an earlier draft document.

A special note of appreciation is due to Betty Pinna for her word processing and graphics support, Katydean Price for her editing, and finally, Nick Naclerio, Defense Advanced Research Programs Agency (DARPA), for his continuous support.

Executive Summary

This document discusses the current status of the Engineering Information Systems (EIS) program, which recently underwent a final review of the prototype design specifications. The document concludes that the EIS design specifications comply with a majority of the original IDA developed EIS requirements; however, additional careful planning and risk analysis are needed. The program is entering the prototype demonstration phase, and given the maturity of selected technology areas, some of the desired functionality is not yet in place. Additional functionality that would provide incentive for adoption and use is needed, and some of this functionality depends on research-level results.

The effectiveness of the EIS program would be greatly improved by the adoption of selected non-technical developments. The first is *an effort to promote effective transition to industry*, the likelihood of which can be strengthened by early recruitment and education of champions within appropriate DoD and commercial sector organizations. Even more fundamental to the success of the program is *high quality user documentation* for all classes of expected users.

The document details a number of needed tasks and provides suggestions for future considerations. Mechanisms for EIS evolution and technology integration are discussed in some detail, including the role of demonstrations, standards organizations, and early technology application into particular programs.

The need for an EIS capability is growing with each technology advances. Future efforts should focus on opportunities to develop, implement and integrate EIS technologies. Recommendations resulting from this study include the following:

a. DoD should establish EIS development and implementation priorities based on the needs of targeted application domains.

b. DoD should expand the research and development efforts in six identified EIS related technology areas.

c. DoD should investigate opportunities to broaden the scope of the EIS program through the interaction with other DoD programs and additional prototype demonstrations.

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1. INTRODUCTION

1.1 PURPOSE

IDA Document D-693, *Interim Status and Recommendations for the Engineering Information System (EIS) Program*, provides an analysis of the EIS framework performed by the Institute for Defense Analyses (IDA). IDA evaluated the present work on the EIS, made recommendations for improving the effectiveness of EIS products, and identified the needed tasks and future considerations. This document is the result of tracking the program implementation, starting with the original requirements and progressing through in-process documents produced for the EIS program, and discussions from meetings and workshops with the EIS contractors and Advisory Committees.

1.2 BACKGROUND

The original requirements documents [Linn et al. 1986a, 1-1,1-2] described the problems faced by the Department of Defense (DoD):

> The complexity of engineered systems is increasing dramatically. Advances in the miniaturization of electronics have increased the complexity of electronic designs by an order of magnitude within the last few years. Further, the advent of VHSIC technology promises to increase the complexity of single-chip designs by another order of magnitude.
>
> The complexity of current systems already is so great that it would be practically impossible to carry out the engineering process without computer assistance. Thus, many different tools and support systems for computer aided design (CAD), computer aided manufacturing (CAM), computer integrated manufacturing (CIM), and (generically) computer aided engineering (CAE) have been evolved and continue to be introduced. Since these tools essentially shoulder a portion of the complexity of an engineered system, the amount of complexity that engineers

must bear is substantially reduced.

Yet, the usefulness of these tools and systems is reduced in the current situation since no particular vendor has an integrated tool set that performs all of the steps needed and/or desired for engineering a system from the requirements phase, through specification and design, all the way to manufacturing and maintenance. Thus, the creation of an adequate tool set requires that tools from different vendors be integrated into the tool set. The problem here is that tools from different vendors utilize different models and formats for representing the same information in a design. Different user interfaces are employed; similarly, different approaches are used in implementing administrative and management capabilities. These differences create additional complexity in the engineering process; the elimination of this complexity would allow the potential productivity gains from CAE tools to be more fully realized.

A second problem brought about by the increased complexity of engineered systems is that it is no longer possible in most cases for a single engineer to design the entire system. Rather, complex designs must be subdivided into smaller units and the designs must be handled by design teams rather than by individual designers.

The decomposition of a design often creates highly interrelated subtasks that must be pursued concurrently, yet the designers must use or revise each other's results. Thus, there is a need for controlled sharing of the design information, tracking of design information, tracking of design dependencies and changes, and monitoring of the design process. In short, there is a need for a system that provides database management functions for engineering information.

In response to these problems, an Engineering Information System (EIS) was conceived that provides a framework for tool integration based on information sharing. In this document, the term EIS is used to describe the particular system whose concepts and requirements are defined in this document and not in a generic way. Like an operating system, the EIS offers facilities and defines interfaces to be used by applications. Also like an operating system, the EIS controls and allocates resources (here, data resources), provides concurrency controls, archiving, and an ad hoc query capability.

The referenced requirements documents have established the need for the following basic EIS functions:

a. Tool Integration: The system must possess the ability to integrate a variety of tools with different data and hardware requirements in an efficient and uniform manner.

b. Data Exchange: The system must possess the ability to translate and communicate data among different hosts and tools within an EIS as well as between the EIS and external systems.

c. Engineering Management and Control: The system must incorporate facilities to monitor the design process and to impose automatic and manual controls on accessing and modifying data.

d. Information Management: The system must incorporate facilities to describe and control globally available EIS data (including the creation and manipulation of data, the imposition of data validity checking, the management of versions and configurations, the control of concurrent transactions, and the management of backup and archived data.)

e. Administration: The system must incorporate the necessary administrative tools and specifications for managing the data dictionary, other tools, workstations, user profiles, and control rules.

2. CURRENT STATUS OF THE PROGRAM

2.1 PROGRESS SUMMARY

The current phase of the EIS program was based on the set of requirements developed for the Very High Speed Integrated Circuits (VHSIC) Program Management Office by an EIS Requirements Team [Linn et al. 1986b, 2-1]. These requirements outlined the need for a prototype demonstration in conjunction with a large set of short-term (core), extended short term (high priority but not mandatory in the short term), and long-term EIS requirements.

The initial contractor effort has been to develop and document a preliminary design specification for the EIS. The documentation requirements were split originally into three major Contract Data Requirements Lists (CDRL's) deliverables [USAF 1989a, 1989b, 1989c]. These three CDRL items (titled: Software Top Level Design, Interface Design, and Database Design) were combined and delivered as a single document titled: *Specification for Engineering Information Systems*. This document is divided into three volumes. Volume I, *Organization and Concepts*, describes the various components of an EIS and describes how those components fit together and behave. Volume II, *Specification and Guidelines*, defines EIS object types according to a common template, specifies four languages developed under the EIS program, and established system interfaces (portability primitives) and user interface guidelines. Volume III, *Engineering Information Model Administrative Domain and ECAD Domain Model*, defines a model for administrating engineering information and contains an Electronics Computer-Aided-Design (ECAD) domain model for Integrated Circuit (IC) design data.[1] This preliminary design phase was

1. The three-volume contract deliverable is refered to in this document as the EIS design specification.

presented at the Final Design Review by Honeywell at the Greenleaf Conference Center, Florida on November 14-16, 1989.

The EIS program is now moving to implementation of an initial prototype phase. The primary advantage in moving to this phase (prototyping) will be in evaluating the collection of EIS requirements and effects of preliminary design decisions. Initial experimentation with tool transfer and interoperability between two different object-oriented systems will then be possible.

A cross reference between the EIS design specification and the IDA requirements documents [Linn et al. 1986a, 1986b] has now been compiled and made available by the contractor; however, a detailed review was beyond the scope of this effort. Although the current design appears to comply with the majority of the IDA requirements, there may be some inefficient or ineffective (difficult to use) interfaces. It is, of course, not practical to predict the performance of such a complex system. However, given that the prototype is a preliminary design, it is likely to be slow, with respect to other (hard-wired or less flexible) engineering environments. This anticipated condition is due to the extra overhead driven by the use of object-oriented and other generalized interface components.

The prototyping will not result in a complete EIS. Instead it will focus on the ECAD domain and will support continued development of EIS technology. The prototypes will allow users and managers to decide on the value of the EIS concepts as a whole, to assess particular features currently specified in the requirements, to review deficiencies in selected components of the current design, and to re-evaluate the EIS requirements.

2.2 NEEDED TASKS AND FUTURE CONSIDERATIONS

2.2.1 Areas of Concern

2.2.1.1 Portability Services

Portability services revolve around using the Portable Operating System for computer environments (POSIX), X Windows, a set of tools and Ada bindings for X Windows, and a printer interface. The functions of POSIX actually used by the EIS, especially by the higher-level tools, should be enumerated. The issue of whether windows should be the common high-level interface among all EIS systems must be addressed. Similarly the policy question whether each installation develops its own top-level interface must be addressed. If installations develop their own top-level interface, then the User Interface Management System (UIMS) would fail to achieve a uniform EIS that operates across different organizations and on different platforms. This could effect tool portability. One incentive for tool developers to follow the UIMS concept would be to provide a small set of parameterized skeleton tool interfaces. Tools for generating adaptors or wrappers for other tools should be addressed also. The MOTIF effort may achieve this, but its progress must be carefully monitored.

2.2.1.2 Object-Oriented Paradigm

The use of the object-oriented paradigm is not yet proven to be efficient and complete in providing all the necessary views for a large running system. This may be a problem because in the EIS specification, there is no distinction between building and using the system. Although an object-oriented approach may be useful in prototyping, it is not obvious that it will be effective in production: the approach may be difficult, if not impossible, to configure and maintain without management mandated control over the schema, its objects, procedural elements, etc. No large information system has yet been implemented using such a "user defined" specification and flexible implementation technique.

2.2.1.3 Coupling/Granularity of Objects

There is a legitimate concern over the appropriate granularity for the objects contained in the EIS object base. If the modeled objects are very low-level, say a single gate, then the overhead of storing the relationships for the gate in the object base and the overhead of accessing a design "gate-at-a-time" may outweigh the benefits of using the object management system (OMS). Conversely, higher granularity objects, say an entire gate array, would overcome these objections; however, one could not then use the OMS functions to directly query at a gate level. The important issue is how this tradeoff should be balanced.

2.2.1.4 Engineering Environment Services (EES)

The EES is primarily the schema for the Administration domain. The Integrated Computer-Aided Manufacturing (ICAM) Definition model version 1X (IDEF-1X model) has not been validated, and the correspondence between the EES specification and the ability to express administrative needs should be checked and improved as necessary. The objects, attributes, and relationships needed for the EIS prototypes will depend on the application scenario, specific tools choices, and the scope of each prototype. The EIM needs to be completed, with both a decomposed data flow model and an IDEF-1X object model, taking account of whatever tools and EES capabilities are in the prototypes. This model is simply intended to document features that are deemed necessary in an EIS.

2.2.1.5 Implementation Hierarchy

The specification should be partitioned into an implementation hierarchy of user-group interfaces with a careful discussion of their "maturity as a term". There should be an enumeration and timeframe assessment of the essential activities, including an explanation of the trade-offs involved in including or excluding a portion of the hierarchy. This will entail a careful discussion of the specific need for each interface and dependence of other portions of the specification on each interface. All interfaces are obviously not at the same level of risk. Some are at low to moderate development risk, with their architecture and implementation obvious; these could be available in one to two years. A higher level of difficulty involves industry research and development (R&D) where implementation should be possible in the two- to three-year time frame. The interfaces at the highest level of difficulty are probably not within the normal industrial workload, and would require research in an industrial laboratory, high technology company, or academia. Such interfaces would need from three to ten years to be developed. Because implementing and using an EIS involvcs interchange of tools, it appears necessary to have interchange in the earliest prototypes. However, there are few, if any, "EIS Service Tools" specified as yet.

One of the major problems of the present user interface is its apparent lack of "user friendliness". The user of a design must be knowledgeable of the object hierarchies and able to deal with objects at a micro-level. For example, "register and deposit a new tool in the library" or "implement the activities of the IDEF model" would require many function calls.

Also required is a prioritizing of object types and methods based on their essential nature to the EIS application domains as a whole. Prospective vendors or providers of future EIS products could develop the most important object types first. Such analysis would illuminate any unnecessary appendages, allowing decisions on elements that are not essential but highly recommended. Specification of EIS components which are essential for large federated systems include many interfaces undergoing standardization or which are candidates for standardization, e.g., recovery and concurrent update of protocols and procedures, methods of detecting and protecting from deadlock over the distributed network, and distributed schema management.

2.2.1.6 Multilevel Security

The need for multilevel security in the running EIS must be considered. Areas that should be addressed include recommendations on special evaluation criteria, additional instrumentation required, and the effect on implementation and system performance. Decisions on the level (B2, B3, or even A1) could have far reaching effects.

2.2.2 Specifications

The documentation of the "core" EIS should cover such topics as its extensibility to more effective systems and any layering needs, types of tool coupling that may be needed, etc. This should be application domain independent.

The content and format of the EIS design specification should include a careful statement of the relevance of the specification to various user groupings: framework builders, tool integrators, managers, and end users who need to understand EIS concepts and benefits. Tailored interfaces should be developed, using aggregates of objects, to simplify actions for specific applications or user domains. Groups will have different criteria for their successful use of EIS. For example, EIS users are likely to evaluate the interfaces on their ease-of-use, tool vendors to evaluate the EIS interfaces from a standpoint of effectiveness. Tool builders will need easy linkage to other tools or necessary data structures and also will need to tailor the actions at the interface to improve efficiency of data transfer.

Additional standard or default auditing and management control needs should be enunciated. The specification of the services level must be completed, especially those interfaces that are needed for the EES.

Automated electronic publication of the EIS documentation should be initiated. Users could then use retrieval techniques to guide their queries. Advanced browsing capabilities for the EIS design specification (when electronically available) would greatly expedite development and maintenance tasks: browsing the schema from a user's perspective has not yet been addressed. The Data Repository will be built using objects but the querying mechanisms to be used have not yet been specified.

One of the requirements for the UIMS is flexibility: the users are to be allowed to specify their interfaces. However, this may introduce conflict, because there is also the need to have the same look and feel across systems. The requirement for human factors interoperability suggests a common interface set, but it would not be economical or reasonable to insist on a single look and feel across application boundaries unless this is endorsed by standards bodies. There should be a specification of a possible or "proposed" top-level interface that would include launching of applications and setting user roles, possibly as an expansion of the Monitor's services. This might be considered a user shell.

The configuration management and document management are not well defined. No configuration management tools are listed. Standard reports and descriptions of tools for merging information are needed. The EIS also should provide change history information on tools. The specification should state how EIS can relate similar components. *The ability to maintain an EIS will be a mandatory requirement of any practical system.*

The Application Object Model (AOM) is used to tailor the behavior of inherited objects; the Rule Specification Language (RSL) is used to describe rules that govern the (user-defined) automatic triggering of responses to certain stimuli. However, the definition of the AOM in the specification seems to be immature and incomplete. Similarly, the definition of the Rule Specification Language is inadequate. There is little evidence that the built-in predicates provide a complete or consistent base definition. Interim rule specifications based on Object-Oriented Design Language (OODL) are likely to be somewhat inefficient. (Of course, rules may be specified in a conventional programming language. Such a technique will be flexible and efficient but will be relatively inconvenient and less maintainable than rules specified in RSL.)

2.2.3 Prototypes and Demonstrations

The planned prototype demonstration should be reviewed to ensure that it has a sufficiently broad basis to address perceived major problem areas. The current demonstration effort should attempt to focus on the use of the EIS in a real engineering design and analysis environment. Assessment from this perspective will be needed for program management decision making on future EIS technology development. Application specific questions still need to be addressed. What are the primary technical risks in the EIS concept? What are the economic and other resource factors issues that must be addressed in making a program decision? Is any current technology limitation a barrier to success? If so, will this change with time in the near-term without any additional effort on the part of the EIS Program?

Planning for technical prototypes and for demonstrations of EIS benefits in specific application domains is required. The prototype demonstrations should consider end-to-end EIS testing and go beyond individual vendor interests. It should also include discussion of the goals, evaluation criteria, and instrumentation required, including reasons for selection and utilization of software and discussion of tool application based on exiting or prototyping standards, such as Computer-aided Design (CAD) Framework Initiative (CFI).

Configuration dependency maintenance tools are needed by the engineering development and maintenance programs to address EIS performance from the standpoints of both compilation containment and the flexibility of updating approaches. There will be an evolving need to model the configuration structurally without dependencies but to capture the fine structure. It should then be possible to execute functions that determine if one object is actually affected by a change in another. For example, if only comments were changed in the source file, the Ada or VHSIC Hardware Design Language (VHDL) compiler should not be invoked.

The plan for the prototype demonstration and the plan for the subsequent evaluation process should focus on specific near-term EIS objectives and needs. The following paragraphs highlight specific technical areas that these plans should address. The results of the prototype demonstration should not only be used to demonstrate feasibility, they should be used to support an iterative design and system maturation process.

Two EIS interface languages are Script Definition Language (SDL), a set machine description language, and Interaction Object Definition Language (IODL), a sub-language of SDL. Their motivation and justification are not explicitly stated in the design documentation, though they are obviously intended to capture the behavioral requirements of the UIMS. They carry a risk, as do many other features, since SDL is untried. All EIS tools are supposed to use UIMS during integration of their tools into the EIS. SDL is based on Event-Driven Transition Systems, and though state machines are a common user interface model, they are often too constraining.

The Common Exchange Format (CEF) should be used to demonstrate transmission of data, such as images of even binary files using standard non EIS base types. There will be a need for special tools that will have to be developed to restore image or binary files. Electronic Design Interchange Format (EDIF), the VHSIC formats, and IPC all have their own semantics. They are fully expressible in object format. Though CEF is general, specific translators would have to be constructed to aid the user in moving from CEF to EDIF and back, etc. In addition, they may differ in kind, e.g., for EDIF the translator can only cover EDIF-based domains.

The Engineering Information Model (EIM) covers a very specific ECAD database description for detailed design and layout. It must be extended for broad-based ECAD scenarios. Only the ECAD model domain is currently supported in the EIS design; there is no current (funded) plan to move from this to other domains, though the interaction proposed with PDES test benches may help to alleviate this.

The implementation should be beneficial to all programs. In addition to the objects, attributes, and relationships needed, the EIM should include the complete definition of functions pertinent to each object for supporting the scenario pertaining to microcircuit ECAD physical design and layout; the EIM should also identify specific commercial-off-the -shelf (COTS) tools to be integrated. The scenarios should cover EIS attachment to a conventional PDES relational database server which holds instances of electronic item data. Also, these scenarios should be detailed sufficiently so as to reveal most of the user operations.

2.2.4 Dissemination of EIS Technology

The dissemination of the EIS technology is critical to the future viability of an EIS type system necessary to meet the design environment, support and evalutionary needs of increasingly complex systems. Based on this critical need the EIS Program should pursue the following actions:

a. Develop a plan for technology application and integration, using technical and popular articles, and presentations at conferences on engineering and information systems.

b. Coordinate with major engineering and management initiatives within DoD such as the Computer-Aided Logistics System (CALS), concurrent engineering, integrated diagnostics, weapon systems development programs, and with industry and Government standards organizations by proposing new national and international standards. For example, the ECAD model is neither validated nor accepted by any standards body; ensuring acceptance in this sense must also be an active effort.

c. Develop and manage a road map for EIS technology improvement and insertion.

3. OPPORTUNITIES FOR EIS EVOLUTION AND TECHNOLOGY INSERTION

This section discusses the opportunities for EIS technology insertion and application through prototypes and demonstrations, support from standards organizations, and targeted implementation in on-going program areas.

3.1 USE OF PROTOTYPES AND DEMONSTRATIONS

The EIS prototype will represent the first opportunity for EIS technology application. In addition to demonstrating the feasibility of the EIS concept, it will allow users first-hand experience, answer questions regarding large systems implementation, and provide a test bed for tool vendors. Recognizing that some of the technology is closer to basic research than development, many tool vendors will avoid the potential risks associated with technology insertion until benefits have been demonstrated.

Therefore, future prototyping should address representative sets of EIS System Administrator tools necessary for installing, operating, and maintaining the EIS. Multiple prototyping efforts should be considered to demonstrate effective, non-laborious ways for the Administrator to set up controls for user and server interfaces, establish and control multiple disparate views, modify the Installation Schema (while maintaining object base or adapter integrity accordingly), and initialize, monitor, and recover the EIS system in spite of hardware or software failure.

Prototyping provides opportunities to investigate alternative interfaces, with particular attention given to reference Schema extension, use of COTS tools common to the prototypes and current Product Data Exchange Specification (PDES) test bed, and CEF interchange of product description data.

The implementation of EIS Prototypes will ultimately benefit a number of programs. In addition to the objects, attributes, and relationships needed, the EIM will eventually include the complete definition of functions pertinent to each object for supporting microcircuit ECAD physical design and layout. Prototype application EIM's will also help identify specific COTS tools for integration. Future prototyping scenarios should cover EIS integration of conventional relational database servers which hold instances of microcircuit reference data or hosts ECAD application tools. This will provide opportunities for designs to be detailed or decomposed to a point where most of the user operations are revealed.

3.2 SUPPORT FROM STANDARDS ORGANIZATIONS

A recommended approach for technology insertion is to evaluate components of the EIS for potential standardization and establish potential ways for implementing the process. Standards can reduce overhead and maintenance costs, provide consistency, and increase productivity. No single vendor possesses the best total solution — thus it is necessary to produce standard interfaces and buy tools that use this though a free market model.

An EIS framework for standards development requires a core of EIS which is application insensitive and upon which application views can be configured. Standards organizations such as the American National Standards Institute (ANSI) seldom develop the material. *Ad hoc* bodies do so, but this then requires a transition phase. Figure 1 depicts a model of the EIS standards interface; apart from the UIMS area shown shaded, standards *development* takes place in the generic environment of the core. Then the application-specific *standards* can be developed by other (or even the same) body.

The EIS contractor should be encouraged to interact continuously with the Contracting Officer's Technical Representative (COTR) to identify and recommend appropriate standards initiatives. This should include the boundary (or boundaries) of the EIS core and ways of providing particular application views.

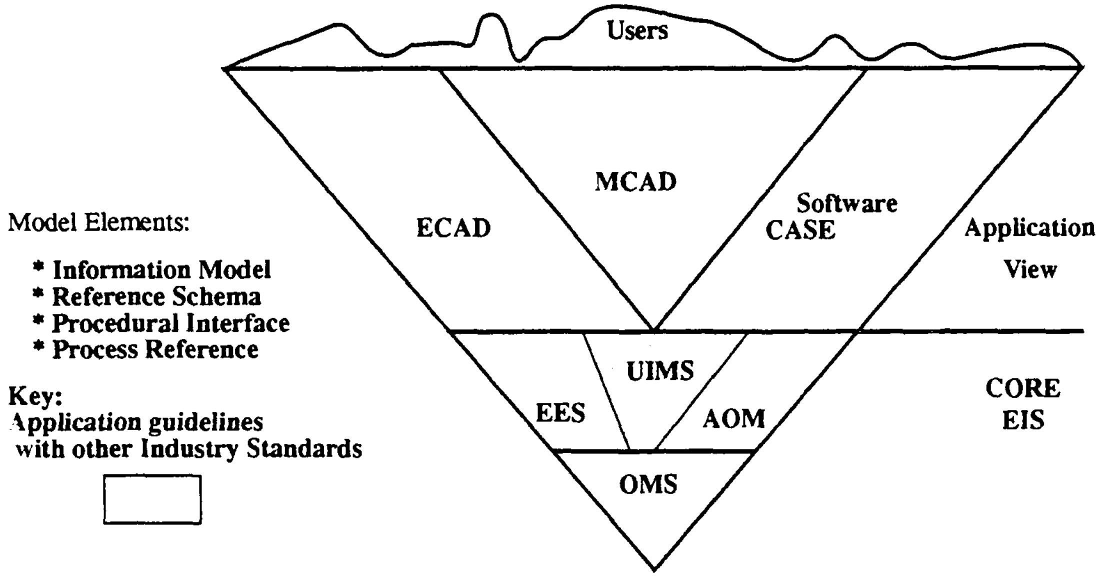

Figure 1. A Model of the EIS Standards Interface.

A possible impediment to satisfactory standards development for an integrated activity such as the EIS is the present nature of standards-making bodies. Very little overlap is observed between similar working groups in separate organizations. There should be a single congruent model of the recommended prime standard for engineering activities. DoD leadership might consider joint sponsorship of allied working groups, as this could have significant pay-off, especially where one group currently creates the standard document which another ratifies. For example, CFI could lead the standards strawman development effort and address objections, while the Design Automation Standard Subcommittee (DASS) could ballot and ratify the standard, preferably with the same working group participants. Such efforts may start with a simple memorandum of understanding and progress further later.

Four basic representations are reflected in the overall model in Figure 1. These are the information model, a reference schema generation method, procedural binding for non-object style programming of tools and user interfaces, and one or more process reference models. But there is still need for a conceptual model to have a common definition across all standards, including a common glossary of terms and an agreement between groups on the focus.

The need for Computer-Aided Software Engineering (CASE) and information requirement standards is great for expressing the future requirements. The transfer of EIS data, models, and final designs demand mutual agreement between standards organizations and EIS component vendors.

3.3 IMPLEMENTATION IN PROGRAM AREAS

Many parts of the EIS have interfaces that are useful to DoD and other Government programs as well as the industrial sector (via National Institute of Standards and Technology (NIST), PDES Inc., etc.). Such interfaces are illustrated in Figure 2, which is also annotated with the main strawman inputs from the EIS efforts to standards bodies.

Current products of the EIS program are the generic engineering information management system specification and the specific information model for microcircuit electrical design (ECAD). Future EIS products and development efforts should include the following:

a. Usable EIS prototypes with an object management capability and object-oriented system tools to allow further demonstration with the prototypes.

b. Validated specifications and guidelines for implementation of EIS environments.

c. Validated installation schema development methodology that can be tailored to any required user development methodology. A complete example must be provided to show the generalized methods and capabilities, as well as the resulting products, such as the documents to act as guidelines.

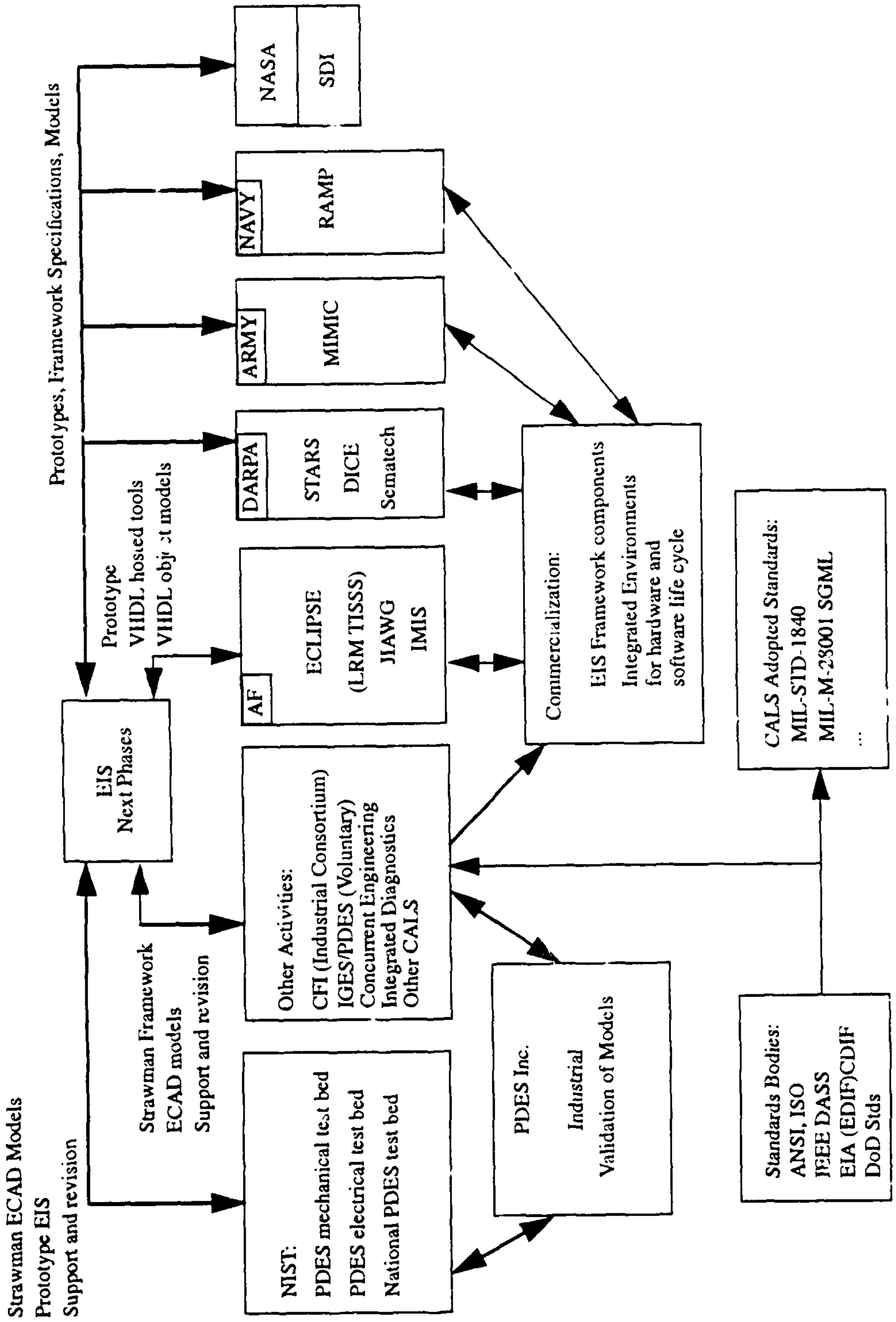

Figure 2. Some Potential Program Users of EIS.

d. Default EES for engineering applications Administration Reference Schema and support tools to provide an initial capability for prototype users.

e. A tool wrapper generator, with examples of developed specific tool wrappers and a set of guidelines on methods and means of invocation of procedures in scenarios that illustrate the addition of tools, etc.

4. PROGRAM RECOMMENDATIONS

4.1 ESTABLISH DEVELOPMENT PRIORITIES

The EIS Specification appears challenging to implement. Therefore, DoD should establish priorities for each portion of the EIS to determine which components should be built first and which are optional. From a long term DoD perspective, the highest priority items are application independent such as the object management system (OMS), configuration manager, security objects, and portability, services. However, for the EIS to be applied productively, it must have the ability to interface with, and support communications between, specific application domain tools. Consequently, additional implementation priorities should be established based on the needs of targeted application domains that are critical to development and support of DoD system as well as standardization initiatives. See Figure 2 for illustration of potential users.

4.2 R&D EFFORTS REQUIRED FOR FUTURE EIS

As discussed in the Background section, there exists a compelling need to integrate the engineering design, development, production, support and evaluation information across a variety of automated tools. However, several of the technology areas necessary to evolve and mature an EIS system require focused research and development. The following recommended R&D areas are critical to future EIS evolution:

a. Development and integration tools to support EIS development and use.

b. Automation techniques for generation of reference schema from information models.

c. Development of a variety of interface sets for distinct user groupings.

d. Development of performance models for federated and workstation environments.

e. Development of a security model for federated systems and workstations.

f. Development of federated information models to incorporate existing non-information models and standards for various application domains.

4.3 EXPAND PROGRAM SCOPE

Due to significant long term benefits and payoffs that will result from a mature EIS capability, DoD should reassess the scope of the current program and investigate opportunities to broaden the implementation of EIS, specifically the EIS program Office should:

a. Investigate the needs and requirements of other DoD programs and ongoing initiatives that have the need to integrate tools and information from a variety of sources, and propose prototype demonstrations for the specific target domains.

b. Provide technical assistance in the technology integration and application of EIS technologies.

c. Establish specific memoranda of agreement with other programs and between individual programs whose mutual technical benefits can be achieved. The interrelationships and potential benefits are illustrated in Figure 2.

d. Develop an overall plan for the services and DoD to propose, validate, and implement critical "core" EIS interface standards that will facilitate the integration of different vendor's tool sets over a broad range of electrical, mechanical and software domains.

APPENDIX A - MINI-SCENARIOS FOR COOPERATION AND TECHNOLOGY INSERTION

Standard interfaces frequently reduce overhead and maintenance costs of purchased tools and other software, while providing consistent framework and improving productivity. No single vendor possesses all of the best and accepted solutions; thus it is necessary to acquire tools that interface and interact correctly. Consequently, it is valuable and cost-effective for the DoD to support standards activities. Furthermore, as systems become more complex, integrated engineering information design environments become a necessity.

This appendix addresses possible interactions and informal arrangements between EIS and important related groups generally, standards bodies and other large DoD R&D efforts. The preferred approach to EIS technology insertion suggested in this section is intended to focus on demonstration and prototyping efforts that yield mutual benefits to all participating parties. Specific discussion of demonstrations and prototyping, and of development of new technology for insertion into for the EIS are addressed in other parts of the document. Discussions here are, therefore, intended to serve as catalyst for major associated standards and industry groups and to promote the insertion by transitioning technology to other DoD efforts.

1. SUPPORT OF VARIOUS STANDARD AND INDUSTRY BODIES

Several standardization and industrial consortia efforts are currently being supported under the EIS contract:

a. CFI and CFL

CAD Framework, Inc. (CFI) is a consortium of Computer-Aided Design (CAD) users and vendors dealing with the transfer of data between tools. The standards activities are through a bottom-up, consensus-based operation. CFI is creating a model for EDA tools and firmware environments to integrated system solutions. They will demonstrate a simple six-item netlist model as an illustration of their concept at the Design Automation Conference (DAC) in June 1990. This will show that different vendors can produce and apply an agreed-upon model. The effort is currently under the direction of Microelectronic Computer Corporation (MCC) personnel. MCC is also taking the active role in development of the CAD Framework Lab (CFL), which will test and evaluate the CFI strawman standards. Now that MCC is a member of the EIS Team, opportunities for EIS technology transfer to CFI and the CFL should be improved.

b. PDES

PDES activities have centered on product descriptions for mechanical design. PDES will extend activities into the electrical domain, working with national standards organizations (e.g, Institute of Electronics and Electrical Engineers (IEEE), Electronics Industries Association (EIA)). The various standards development organizations for PDES product information will express the components of PDES in a language conforming to existing standards efforts, but then will convert or relate semantic components to a common integrated information model (using the Express language).

(1) PDES voluntary is a group supporting the development of PDES electrical in the Electrical Application Committee, using the PDES Information Modeling Methodology.

(2) ANSI PDES Electrical Engineering standards are now under the guidance of an organization with a board consisting of EIA, IEEE, Institute for Interconnectivity and Packaging Electronic Circuits (IPC), andAmerican Society of Mechanical Engineers (ASME). Task groups will typically work in the information model language, integrated model, implementation, validation & test, and standards taxonomy.

(3) PDES Inc. is providing industrial validation of PDES standards. The national PDES electrical effort will be guided by subcommittees, reporting to ANSI. The PDES committee has two active subcommittee members from the EIS team.

(4) NIST is providing a PDES testbed. At present there are discussions regarding the

integration of an EIS prototype into the NIST PDES testbed. EIS/ECAD model extensions also should be integrated with the PDES models. This effort could yield a multidomain demonstration.

c. IEEE/DASS

DASS is chartered to provide standard descriptions for capture, utilization, and communications of electrical engineering design data. It handles system to layout levels of design. The IEEE/DASS effort is an actual standardizing organization (i.e., they take developed proto-standards and ratify them). Thus CFI's strawman effort, having developed the proposed standard and addressed any early objections, could pass the final drafts to DASS for final balloting and ultimately ratification of the standard. Current work being supported under EIS therefore includes routing PDES and CFI strawman standards to the IEEE/DASS standards process. At present two subcommittees are staffed by EIS contractor personnel. Efforts should continue to support models and frameworks.

d. Semantic level portability Services (EDIF, CDIF, etc.)

CASE and information requirement (e.g., IDEF-like) standards are good for expressing system requirements. Transfer of EIS data, models, and final designs demand mutual agreement between standards organizations and EIS component vendors. Although the CFI will provide low-level interchange, higher order semantics are possible using other protostandards. EDIF and CDIF are two EIA-sponsored standardizing bodies developing standards for interchange of electronic circuit and software engineering (CASE) tool information. The latter effort is also being considered by the IEEE Computer Society Task Force on Professional Computing Tools.

e. MOTIF, OPEN/LOOK, and other UIMS Prestandards

There are several pre-standardization organizations addressing the issue of the user interface, e.g., MOTIF, OPEN/LOOK, and the Athena/X consortium. Their work should be monitored, but until there are positive recommendations from them, the design of interfaces effort should probably be left to specific vendor implementations or general workstation industry standards.

2. FEDERAL SUPPORTED EFFORTS

Many major DoD and other Governmental efforts have common requirements for data interchange, both for transfer between contractor and vendors and for dissemination of various documents, design layouts. Ones specifically showing interest in EIS products at present include the following:

a. Microwave and Millimeterwave Monolithic Integrated Circuits (MIMIC)

The MIMIC office at Ft. Monmouth is supporting the development of CAD environments for MIMIC circuits; they intend to choose two frameworks as their approved CAD platforms. They would like to use the EIS concepts in achieving standardization of their CAD environments. Current plans involve extension of the ECAD model to support analog devices and then to build a demonstration using MIMIC tools operating to the model. One of the current frameworks (Cadence or Silicon Compilers) would probably be used in this demonstration, and it would then be migrated as the EIS platform.

b. Microelectronics Manufacturing Science and Technology (MMST)

The MMST Program Office would like to integrate the EIS and MMST technologies to aid in efficient design-to-manufacture transition for IC. The EIS ECAD model can be integrated with the MMST information models and then the EIS prototype could be combined with the MMST/CIP processors to achieve this. It might even be possible to use the EIS framework technology in CIP to achieve this result also.

c. Logistics R&D Efforts

Retrofit engineering projects are underway at various Air Force Air Logistics Centers (ALC). They have a need for common repository and data exchange technology and tools, and feel that the EIS framework and modeling technologies provide a possible solution. A demonstration scenario would include model extensions to different life cycle phases and an integrated environment for design and support phases and interface to manufacturing.

(1) Sacramento ALC is undertaking development of a logistics retrofit process activity for gate arrays and VHSIC.

(2) Warner-Robbins ALC is undertaking some specific retrofit projects (RFP). They need an appropriate design and lifecycle support environment.

d. JIAWG

The Joint Interoperable Avionics Working Group (JIAWG) is a tri-service operation dedicated to providing efficiency in avionics procurement through reuse of avionics hardware and software. This is being showcased through the program offices for the ATF (Air Force), the ATA (Navy), and LHX (Army). An EIS is needed to integrate avionics systems as the individual environments are defined. The common component libraries and their specifications must be indexed and managed by such a system as a precondition to practical reuse of both hardware and software components. This requires an extension of the domain information model, integrating tools, populating repositories with parts, and developing a demonstration scenario. It is important for EIS personnel to coordinate with JIAWG to avoid duplication of effort, contribute to the success of the interoperability initiative, and provide a demonstration of EIS effectiveness.

e. Software Technology for Adaptable, Reliable Systems (STARS)

The STARS program, now located within the Information Sciences Technology Office (ISTO) of DARPA, has endorsed the concept of establishing an effective functional prototyping technology and process to articulate the software cost/benefit trade-off alternatives. Among the other benefits of taking an EIS approach to integrated hardware/software systems is concurrent development of hardware and software for improved allocation of functionality and more efficient and effective integration, integrated diagnosis/support platforms, and sharing of repositories for hardware and software designs.

f. NASA Space Station

The work at NASA in Reston and Houston in developing the Space Station information systems is yet another effort dealing with large back-plane environment developments for interchange of design, configuration, and runtime data. In addition, there are software support and production environments and Technical and Management Information Systems. As a massive systems development and integration project, the Space Station can benefit from DoD EIS activity, provide further potential tests and applications of EISs, and promote technology transfer. Both DoD and NASA would gain from cross fertilization of ideas if not integration of some efforts. EIS representatives should develop and maintain contacts with NASA Space Station projects.

g. SDI

The development and simulation environments of the Strategic Defense Institute (SDI) have many problems in common with the development of multi-vendor engineering systems. In many ways, they are similar to the Space Station developments mentioned, in that they involve the development and deployment of unprecedented mission critical systems requiring massive integration, fault detection and repair, and long-term maintenance and evolution in an extremely difficult environment. There should be some liaison with EIS, as this projected system involves a degree of complexity that requires the use of engineering information systems.

APPENDIX B - ACRONYMS

ALC	Air Logistics Center
ANSI	American National Standards Institute
AOM	Application Object Model
ASME	American Society of Mechanical Engineers
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAIS-A	Common Ada Programming Support Environment (APSE) Interface Set - [version] A
CALS	Computer-Aided Logistics System
CAM	Computer-Aided Manufacturing
CASE	Computer-Assisted Software Engineering
CDIF	CASE Design Interchange Format
CDRL	Contract Data Requirements List
CEF	Common Exchange Format
CFI	Computer-Aided Design (CAD) Framework Initiative
CFL	Computer-Aided Design Framework Laboratory
CIM	Computer-Integrated Manufacturing
COTS	Commercial Off-the-Shelf Software
COTR	Contracting Officer's Technical Representative
CSED	Computer and Software Engineering Division
DARPA	Defense Advanced Research Projects Agency
DAC	Design Automation Conference
DASS	Design Automation Standard Subcommittee
DICE	DARPA Initiative in Concurrent Engineering
DoD	Department of Defense
ECAD	Electrical Computer-Aided Design

ECLIPSE	Electric Capability for the Logistics Information and Product Support for Electronics
EDIF	Electronic Design Interchange Format
EES	Engineering Environment Services
EIA	Electronics Industry Association
EIM	Engineering Information Model
EIS	Engineering Information System
ICAM	Integrated Computer-Aided Manufacturing
IDA	Institute for Defense Analyses
IDEF	ICAM Definition Method
IEEE	Intitute for Electronics and Electrical Engineers
IMIS	Integrated Maintenance Information System
IMM	Information Modeling Methodology
IO	Interaction Object
IODL	Interaction Object Definition Language
IPC	Institute for Interconnectivity and Packaging Electronics Circuits
ISO	International Standards Organization
JIAWG	Joint Interoperable Avionics Working Group
LRM	Line Replaceable Module
MCC	Microelectronic Computer Corporation
MIMIC	Microwave and Millimeterwave Monolithic Integrated Circuits
MMST	Microelectronic Manufacturing Science and Technology
NASA	National Aeronautics and Space Administration
NCGA	National Computer Graphics Association
NIC	Non-Interative Components
NIST	National Institute of Standards and Technology
OMS	Object Management System

OODL	Object-Oriented Design Language
PCTE	Portable Common Tool Environment
PDES	Product Data Exchange Specification
POSIX	Portable Operating System for Computer Environments
R&D	Research and Development
RAMP	Rapid Area Manufacturing Program
RSL	Rule Specification Language
SDI	Strategic Defense Initiative
SDL	Script Definition Language
SSE	Space Station Environment (NASA)
STARS	Software Technology for Adaptable, Reliable Systems
TISSS	Tester Independent Software Support System
UIMS	User Interface Management System
VHDL	VHSIC Hardware Design Language
VHSIC	Very High Speed Integrated Circuits

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